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Project Description

Outcomes of the LIFE INVASAQUA project: An integrated approach for the prevention and awareness of aquatic invasive species in the Iberian Peninsula

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Abstract

Invasive alien species (IAS) pose a growing threat to biodiversity, ecosystem services and human well-being, particularly in aquatic ecosystems worldwide. These species lead to severe environmental and economic impacts by altering habitats, disrupting ecological processes and outcompeting native species. In the Iberian Peninsula, IAS represent a major risk to its unique freshwater and estuarine ecosystems, which are particularly vulnerable to biological invasions due to their connection to human activities and high number of endemic species. Awareness of IAS and their impacts among the general public and stakeholders in Spain and Portugal remains limited, hindering effective management strategies and policies. The LIFE INVASAQUA project (2018–2023), co-funded by the LIFE Programme of the European Commission (LIFE17 GIE/ES/000515), aimed to support management, communication and the dissemination of information on aquatic IAS in the Iberian Peninsula. To achieve this, diverse partners were involved, including universities, research institutions, an environmental news agency and NGOs. Key actions included the production of governance tools such as strategic recommendations and IAS priority lists and communication resources such as a traveling exhibition for the public and codes of conduct for stakeholders. The project delivered 98 training activities to over 2,900 participants and engaged more than 430 institutions and 246,000 people through 598 public events in Spain and Portugal. LIFE INVASAQUA significantly enhanced public awareness and transnational collaboration, evidenced by improved communication, increased social media engagement, and positive shifts in public perception, as revealed by 7,078 records of a survey

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based on a questionnaire on the Iberian public's perspectives. These outcomes foster strengthened IAS management frameworks and support implementation of relevant European and national regulations. The project's long-term efforts focus on developing and replicating actions with the greatest audience reach and the highest impact on public perception of IAS issues. Lessons learned include the importance of sustained public engagement, the need for continued stakeholder collaboration, and the effectiveness of integrating educational campaigns with policy enforcement for sustained success in IAS management.

Key words: Biological invasions, communication, freshwater systems, governance, public engagement, transnational management

Introduction

Biological invasions occur when species introduced beyond their natural ranges negatively affect biodiversity and ecosystem services, acting as a driver of global change with ecological, health and economic impacts (Diagne et al. 2021; IPBES 2023). Human activities such as globalization and habitat alteration influence their rapid spread (Seebens et al. 2017; Hulme 2021), while climate change creates favourable conditions for their establishment (Gallardo et al. 2018).

Europe has witnessed a rapid increase in IAS introductions over the last five decades, and projections foresee a 64% increase by 2050 (Seebens et al. 2021). Type and severity of impacts are unevenly distributed across Member States (MS) and biogeographic regions, with areas such as the Iberian Peninsula facing heightened vulnerabilities. This is due to its high freshwater and estuarine endemicity, varied environmental gradients and type of ecosystems and its connection to humans' activities that favours IAS establishment (Muñoz-Mas and García-Berthou 2020; Oficialdegui et al. 2023a). The Regulation EU 1143/2014 on IAS (EU Regulation on IAS) emphasises the need for harmonised efforts to prevent IAS introductions, establish surveillance systems, and implement effective management. This requires robust transnational collaboration, as their impacts often extend beyond national boundaries. Coordination among governments, international entities, NGOs, and local stakeholders is essential to tackle fragmented management practices and implement cohesive strategies. Early stakeholder engagement during the planning and execution phases fosters shared responsibility, enhances monitoring efforts, and facilitates the exchange of best practices across regions. Integrated actions, legislation and sound governance frameworks are essential for achieving meaningful progress in IAS management (Magliozzi et al. 2024).

Inland waters are particularly vulnerable to biological invasions due to their high connectivity with human activities, which facilitates the introduction and spread of IAS through pathways such as angling, recreational boating, and the pet trade (Nunes et al. 2015; Hulme 2021). These ecosystems are also frequently altered by anthropogenic pressures, including water regulation, pollution, and habitat fragmentation, further increasing their susceptibility to new species arrivals. As a result, IAS have become one of the primary threats to endemic aquatic biodiversity, leading to declines in native species and alterations in ecosystem structure and functions (Gallardo et al. 2016; Flood et al. 2020; McFadden et al. 2023).

The Iberian Peninsula harbours unique freshwater and estuarine ecosystems increasingly threatened by biological invasions, which are exacerbated by intensive human activity, habitat degradation, and climate change. In particular,

a high number of endemic Iberian aquatic species are vulnerable to competition, predation, and habitat alteration caused by IAS (Doadrio 2001; Cruz and Rebelo 2005; Verdú et al. 2011; Ruiz-Navarro et al. 2013; Boieiro et al. 2023; Magalhães et al. 2023).

While the global economic costs of IAS amount to US$345 billion (Cuthbert et al. 2021), this burden reaches US$140.20 billion across European countries (Haubrock et al. 2021). In Spain, the economic costs associated with IAS between 1997 and 2022 amounted to €232 million (Angulo et al. 2021), which includes, for example, €50 million spent on controlling the water hyacinth *Pontederia crassipes* (=*Eicchornia crassipes*) in the Guadiana River basin (MITECO 2019, Spain) (https://www.miteco.gob.es/en/biodiversidad/publicaciones/pbl_fauna_flora_estrategia_camalote.html), while in Portugal, the economic costs reached US$7.89 billion. However, costs distribution and updated available information are uneven across countries, regions and species (Angulo et al. 2021; Haubrock et al. 2021).

Given that major watersheds are shared between Spain and Portugal, joint governance and transnational cooperation are essential to ensure cohesive and effective management strategies. Both countries face common challenges in managing IAS, including low public awareness, lack of knowledge on government interventions, poor coordination among management authorities and limited funding (Oliva-Paterna et al. 2022). The implementation of the EU Regulation on IAS is anchored in national frameworks in both countries, including the Spanish IAS catalogue (Real Decreto 630/2013) and the Portuguese National List of IAS (Decreto Lei 92/2019). Moreover, Spain is divided into 17 Autonomous Regional Communities with different policies towards IAS and wildlife management, increasing the legal disparities within the country and between countries. Despite these legislative efforts, achieving the regulation's objectives at the national level requires stronger collaboration among administrative agencies and policy makers, NGOs, and stakeholders. In addition, scattered scientific data and technical knowledge exacerbate these challenges (Oficialdegui et al. 2023a; Zamora-Marín et al. 2023). The general public tend to underestimate IAS threats, especially for species without apparent socioeconomic impacts, which further delays policy adoption and reinforces misconceptions about IAS management (Banha et al. 2017, 2022).

Successfully implemented European initiatives such as the LIFE ASAP (Cogoni et al. 2017), AlienScenarios (Essl et. al 2019), InvasiBES (Gallardo et al. 2019), and LIFE ARTEMIS (de Groot et al. 2020) projects underscored the critical role of collaborative efforts in addressing IAS across Europe. These initiatives highlighted the importance of updating available information on IAS distribution and the key areas where further communication efforts should be prioritised to improve the effectiveness of management. The knowledge gained through these experiences emphasises that no single country can tackle biological invasions alone and that cross-border partnerships are essential to address biological invasions. These collaborative projects established principles of replicability for management and communication efforts in other European countries (Roura-Pascual et al. 2024). Their positive impact is evident in emerging initiatives as the LIFE PREDATOR (De Santis et al. 2024) and GuardIAS (Katsanevakis et al. 2024) projects designed to test updated approaches for IAS management and stakeholders' involvement through innovative tools, such as environmental DNA (eDNA), artificial intelligence, nanotechnology and citizen science (Banha et al. 2017; Coya et al. 2025).

In the Iberian Peninsula, the LIFE INVASAQUA project (2018–2023) emerged in response to a pressing need: addressing the persistent challenges posed by aquatic IAS in the shared ecosystems, where isolated national efforts are insufficient. Furthermore, the project aimed to bridge crucial gaps in updated knowledge and capacity building by equipping environmental managers, policymakers, and the general public with essential resources for IAS prevention and management.

Objectives, scope and partnerships

LIFE INVASAQUA (period 2018–2023) was a European Environmental Governance and Information project co-funded by the LIFE Programme of the European Commission. The project addressed the challenges posed by aquatic IAS in the freshwater and estuarine ecosystems of the Iberian Peninsula aiming at improving awareness, governance and management strategies to mitigate the impacts of these IAS. The main objectives of LIFE INVASAQUA were to: (1) provide support and enable the implementation of the EU Regulation on IAS by creating synergies between scientists and managers; (2) increase stakeholder response capacity and awareness of the threats posed by aquatic IAS through extensive communication and training efforts aiming at enhancing early warning and rapid response (EWRR) mechanisms; and (3) raise awareness among the general public about the threats caused by aquatic IAS through a mass communication campaign (Fig. 1).

The project actions framework was designed to strengthen research, promote knowledge transfer and engage stakeholders at both national and transnational levels, thereby ensuring a coordinated approach to IAS management. It targeted a wide range of stakeholders, including public administration officials, environmental managers, surveillance agents, researchers, NGOs, and key user groups such as recreational anglers and water sports practitioners. It also engaged the general public through education and awareness campaigns.

LIFE INVASAQUA brought together a multidisciplinary consortium from Spain and Portugal, including four Universities, a national museum, three NGOs and an international communication agency (Fig. 1).

All partners were involved in a wide range of project actions, promoting collaboration and synergies amongst them, including public dissemination activities. For example, the universities of the consortium and the Iberian Society of Ichthyology (SIBIC) focused on knowledge transfer and governance initiatives by developing IAS prioritisation lists and strategic management guidelines. The consortium NGOs focused on public engagement activities such as citizen science initiatives, volunteering and educational activities. The Museum of Natural Sciences (MNCN-CSIC) played a key role in targeting the general public by implementing a travelling exhibition and also supporting training actions for stakeholders. The International Union for Conservation of Nature (IUCN-Med) also promoted the transferability and replication plan while EFE Verde communication agency was mainly in charge of developing and implementing the communication strategy. In addition, 30 pre-established agreements were set with a wide range of entities, such as private companies, consultancies and diverse NGOs to ensure stakeholder collaboration, fostering a unified response and facilitating the exchange of best practices in IAS management.

The project was funded by a total budget of 3,075,139 € (59.99% co-funded by the LIFE Programme of the European Commission).

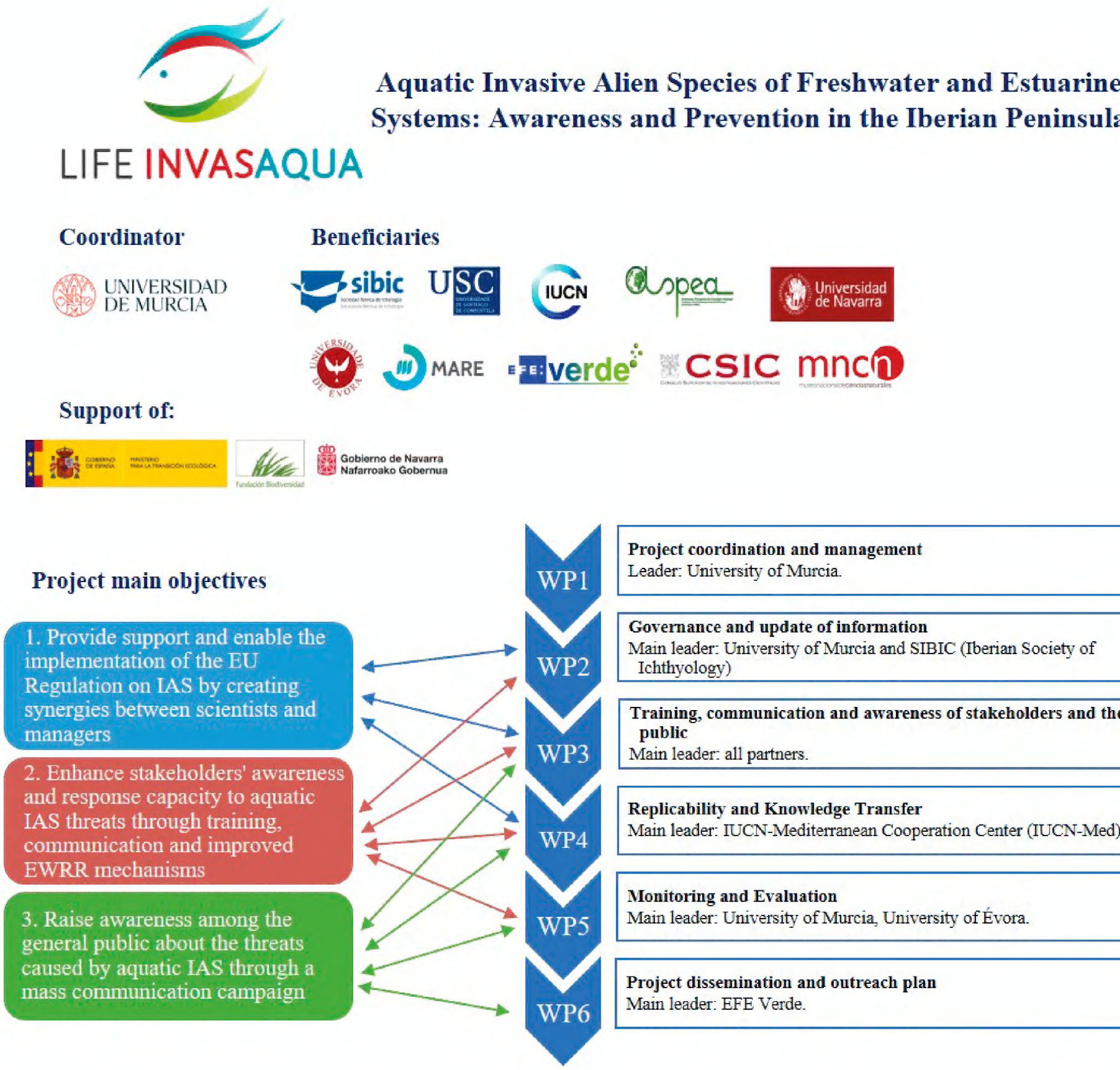
LIFE INVASAQUA
Aquatic Invasive Alien Species of Freshwater and Estuarine Systems: Awareness and Prevention in the Iberian Peninsula
Coordinator
Beneficiaries
UNIVERSIDAD DE MURCIA
sibic
USC
IUCN
aspea
Universidad de Navarra
MARE
EFE verde
CSIC
mncn
Support of:
Gobierno de Navarra
Nafarroako Gobernua
Project main objectives
1. Provide support and enable the implementation of the EU Regulation on IAS by creating synergies between scientists and managers
2. Enhance stakeholders' awareness and response capacity to aquatic IAS threats through training, communication and improved EWRR mechanisms
3. Raise awareness among the general public about the threats caused by aquatic IAS through a mass communication campaign
WP1
Project coordination and management
Leader: University of Murcia.
WP2
Governance and update of information
Main leader: University of Murcia and SIBIC (Iberian Society of Ichthyology)
WP3
Training, communication and awareness of stakeholders and the public
Main leader: all partners.
WP4
Replicability and Knowledge Transfer
Main leader: IUCN-Mediterranean Cooperation Center (IUCN-Med)
WP5
Monitoring and Evaluation
Main leader: University of Murcia, University of Évora.
WP6
Project dissemination and outreach plan
Main leader: EFE Verde.

Figure 1. Framework of the LIFE INVASAQUA project. At the top, the project logo is displayed followed by the University of Murcia (coordinator) and beneficiaries' logos: the Iberian Society of Ichthyology (SIBIC), the University of Santiago de Compostela, IUCN - Centre for Mediterranean Cooperation (UICN-Med), the Portuguese Association for Environmental Education (ASPEA), the University of Navarra, the University of Évora (UEV) together with the Marine and Environmental Sciences Centre (MARE), EFE news agency (EFE Verde section) and the National Museum of Natural Sciences (MNCN-CSIC). Those are followed by the logos of the supporting entities (Ministry for Ecological Transition and the Demographic Challenge – Fundación Biodiversidad and the Government of Navarra). The connections between the specific objectives and Work Packages (WPs) are shown below, highlighting the leading partner for each WP.

Structure and approach

The project was organised into six Work Packages (WPs) (Fig. 1), each designed to address a specific aspect of IAS management in the Iberian Peninsula. This structure ensured a comprehensive approach, combining governance, training of relevant key groups, awareness, scientific innovation, and stakeholder engagement. The coordination between partners allowed for the efficient execution of activities, from developing strategic tools and educational campaigns to fostering transnational cooperation. By systematically organizing its actions, LIFE INVASAQUA achieved impactful and sustainable outcomes, setting a benchmark for future IAS management initiatives.

Key actions, milestones and results

The University of Murcia led the project, facilitating communication and collaboration among all partners and overseeing project activities. It also included efficient administrative and financial management, ensuring the optimal use of project resources, with comprehensive budget tracking and timely submission of financial reports.

A robust framework of metrics and indicators developed within WP5 (Fig. 1) was implemented to evaluate the effectiveness of the project's actions and to adapt audiences and strategies when necessary. Key elements included setting baseline indicators (e.g. number of participants engaged and materials distributed), conducting continuous monitoring through the project survey based on questionnaire and final reporting to evaluate the project reach and impact (Oliva-Paterna et al. 2024a, 2024b). This framework comprehensively covered public awareness, stakeholder engagement, communication strategies and the adoption and use of management tools.

More than 7,000 questionnaires were analysed to assess changes in public perception and understanding of IAS impacts on biodiversity, socioeconomics and human health. Specific information on the design, structure and formulation of questions of the survey is detailed in the preliminary assessment study developed by the project (Banha et al. 2022). An additional young people´s version of the survey (shortened and simplified) was prepared specifically for school students and specific information on this version is detailed in Ruiz-Navarro et al. (2023).

Overall participation and engagement metrics of the project exceeded expectations, with more than 246,000 people attending 598 events, and direct engagement of 432 institutions including public administrations, NGOs, and educational entities.

Support in the implementation of the EU Regulation on IAS

Key management tools (Table 1) were developed within WP2 aimed to enhance governance frameworks for managing IAS in the Iberian Peninsula and to provide updated, science-based information to support decision-making and policy implementation. This included the development of an updated inventory of 326 aquatic IAS recorded in Iberian inland waters, including 215 taxa with clearly established populations (Oliva-Paterna et al. 2021a; Zamora-Marín et al. 2023). Moreover, the project also compiled a list of 272 taxa that had not yet been recorded in Iberian inland waters but show high risk of invasion in the coming years (Oliva-Paterna et al. 2021b). This effort, based on expert input and scientific literature, highlighted the rapid increase of IAS introductions, particularly in the last two decades (Zamora-Marín et al. 2023). Through a transnational horizon scanning exercise, scores were assigned to IAS following various criteria (e.g., invasiveness, impacts, management difficulty and acceptability) to develop the "Black List and Alert List of the Aquatic Invasive Alien Species of the Iberian Peninsula" (Oliva-Paterna et al. 2022; Oficialdegui et al. 2023a), which included 126 species of concern already established in Iberian inland waters, such as *Cyprinus carpio* (common carp) and *Procambarus clarkii* (red swamp crayfish), and 89 potential aquatic invaders, including *Dreissena rostriformis bugensis* (quagga mussel) and *Cabomba caroliniana* (Carolina fanwort) (Oficialdegui et al. 2023a). The inventories provided a solid foundation for effective future surveillance systems, supported by scientific consensus and promoting coordinated efforts in shared transnational regions.

Table 1. List of the governance tools generated by the LIFE INVASAQUA project and web links.

LIFE INVASAQUA governance tools	Link
Updated list of the aquatic alien species introduced and established in Iberian inland waters. (Oliva-Paterna et al. 2021a).	https://www.miteco.gob.es/content/dam/miteco/es/biodiversidad/temas/conservacion-de-especies/listadeespeciesexoticasacuaticasdelapeninsulaiberica_tcm30-529356.pdf
Updated list of the potential aquatic alien species with high risk of invasion in Iberian inland waters. (Oliva-Paterna et al. 2021b).	https://lifeinvasaqua.com/wp-content/uploads/2021/04/TR2_Invasaqua_ING_PDF_interact.pdf
Black List and Alert List of the aquatic invasive alien species of the Iberian Peninsula – Horizon scanning exercise focused on the high-risk aquatic invasive alien species for the Iberian inland waters. (Oliva-Paterna et al. 2022).	https://lifeinvasaqua.com/wp-content/uploads/2023/01/TechRepp_3_INVASAQUA_Complet_ING.pdf
Strategic recommendations for the transnational management of invasive alien fish in Iberian inland waters. (Oliva-Paterna et al. 2023).	https://lifeinvasaqua.com/wp-content/uploads/2023/02/2023_StrategicRecommendations_Fish_Final_WEB-1.pdf
Strategic recommendations for the transnational management of invasive alien crayfish and crabs in Iberian inland waters. (Oficialdegui et al. 2023b).	https://lifeinvasaqua.com/wp-content/uploads/2023/08/TECHINICAL-REPORT-CANGREJOS-ingles-para-WEB.pdf
Invasive Alien Species web platform	https://eei.sibic.org/

The project also generated the "Invasive Alien Species web platform" (https://eei.sibic.org/) to support monitoring and Early Warning and Rapid Response (EWRR) frameworks, facilitating decision-making and enabling data sharing with the European Alien Species Information Network (EASIN). This tool reached 1,242 users and 5,012 unique visits at the end of the project (October 2023), and included more than 20,000 geo-referenced records on the monitoring of approximately 200 IAS taxa. It also facilitated data sharing in the official languages of Spain and Portugal.

Strategic recommendations for the transnational management of targeted invasive taxa, such as fish (Oliva-Paterna et al. 2023), crayfish, and crabs (Oficialdegui et al. 2023b), were conceptualized, developed and distributed among competent authorities to address shared challenges in Iberian inland waters. These recommendations were developed through a participatory process involving experts, and aimed at strengthening cooperation between Spanish and Portuguese authorities, thus promoting the transnational management and ensuring coordinated actions between Spain and Portugal.

International events and workshops were promoted among Spanish, Portuguese and European competent authorities, managers and projects to disseminate the outputs and be involved in its use and promotion. These events enhanced understanding of IAS-associated issues, facilitated the integration of project outputs into national policies, and promoted a unified response to the IAS threat. Specific actions on knowledge transferability and replicability and dissemination to the public (Fig. 1) such as the development of the IBERMIS platform (https://ibermis.org/) and the project website (http://www.lifeinvasaqua.com/) ensured that resources generated were also accessible online. This aimed at being easily replicable by other entities and projects and that the contents could be updated according to priority changes in biological invasions. The "Exchange of Experiences on Invasive Alien Species Projects in Europe" workshop, hosted in Malaga in May 2023, facilitated the sharing of lessons learned from ongoing and recently finished LIFE projects and other European initiatives. This event highlighted the importance of strengthening synergies among projects to improve IAS management practices across borders. In Brussels, we organized the "Addressing IAS in Europe: The relevance of transnational cooperation and the stakeholder engagement", a high-profile event in collaboration with the European Commission that showcased the outcomes

Figure 2. LIFE INVASAQUA networking events **A** conclusions session of the "Addressing IAS in Europe: The relevance of transnational cooperation and stakeholder engagement" event. Brussels, September 2023 **B** group picture of the "Exchange of Experiences on Invasive Alien Species Projects in Europe" event. Malaga, May 2023.

of LIFE INVASAQUA to EU policymakers and stakeholders (Fig. 2). This event emphasised the project's alignment with the EU Biodiversity Strategy to 2030 and its contributions to enhancing the implementation of the EU Regulation on IAS.

During these events, the "Invasive Alien Species web platform" was highlighted as a model that could be adapted for use in other regions, showcasing its potential for replicability. Overall, the project's engagement with more than 20 LIFE and other European initiatives created valuable partnerships and facilitated a broad dissemination of best practices. These efforts ensured that LIFE INVASAQUA's impact extended beyond its timeline, establishing a framework for IAS management at multiple levels.

Enhancing stakeholders' awareness and response capacity to aquatic IAS threats

Several key actions (Fig. 1) were dedicated to raising awareness and fostering education about aquatic IAS among key stakeholders in Spain and Portugal. It aimed to increase knowledge regarding IAS impacts and to empower individuals and organisations to contribute to prevention, management and mitigation efforts.

The project implemented a dissemination and training strategy in order to reach the target audiences and key stakeholders: surveillance agents, river and estuary users (anglers, aquatic sports practitioners, etc.) (Fig. 3), knowledge multipliers such as museums and aquariums (Fig. 4), the educational community, the commercial sectors (aquaculture, pet-keeping etc.) (Fig. 5), and the media.

The Clean, Check and Dry campaign (Fig. 3) was promoted among river and estuary users to encourage good practices in preventing IAS spread in Spain and Portugal. It was supported by the Spanish Federation of Angling and Casting which hosted the materials and the project survey on its website: (https://www.fepyc.es/blog/consulta-los-ciudadanos-sobre-las-especies-ex%C3%B3ticas-invasoras-%E2%80%93-campa%C3%B1a-revisa-limpia-y-seca-%E2%80%93).

The project developed a total of 98 training activities including 4 massive open online courses (MOOCs) (https://ibermis.org/formacion/), which attracted over 2,900 participants. These training initiatives provided key groups with the tools and knowledge necessary to contribute to IAS management and prevention.

A
Ayuda a reducir la propagación de plantas y animales invasores
REVISA
LIMPIA
SECA
www.lifeinvasaqua.com
B
LIFE17 GIE/ES/000515
LIFE INVASAQUA
PARE
A
INVASÃO
As espécies invasoras de fauna e flora alteram os ecossistemas aquáticos, reduzindo a biodiversidade, afetando atividades como a pesca ou a agricultura e dificultando a navegação. Muitas delas têm um tamanho pequeno e são difíceis de detetar. Sem que nos apercebamos, podemos facilitar a sua propagação, transportando os seus ovos, larvas ou sementes aderidas aos nossos equipamentos, sapatos, roupa e a outros materiais.
Proteja o meio aquático e continue a desfrutá-lo, mantendo o seu equipamento livre de animais e plantas invasoras.
Materiais gratuitos em: www.lifeinvasaqua.com
Lembre-se de inspecionar bem estes lugares
VEJA
VEJA a embarcação (canoa, caiaque, etc.) e o equipamento (remos, botas, luvas, roupa, aparelhos, etc.) e elimine logo os restos aderidos (terra, sujidade, animais aquáticos ou matéria vegetal).
LAVE
LAVE a fundo e o quanto antes, com especial atenção para as áreas húmidas e de difícil acesso do interior e do exterior do barco e do equipamento. Utilize água quente ou lixívia diluída e deixe secar, preferencialmente ao sol e ao ar, durante vários dias.
SEQUE
SEQUE a água que ficou na embarcação com uma esponja ou toalha antes de voltar a usá-la em outro local, pois algumas espécies invasoras podem sobreviver durante semanas em ambientes húmidos.
TENHA CUIDADO COM ESTAS ESPÉCIES:
Amêijoa-asiática
Azola
Mucor-de-pedra
Coordenação:
Sócios beneficiários:
Com o apoio de:
Gobierno de Navarra
Nafarroako Gobernua
@LifeInvasaqua

Figure 3. Visuals of the Check, Clean and Dry campaign **A** campaign logo (Spanish version) **B** dissemination poster for the navigation sector (Portuguese version). All high-quality materials in Spanish and Portuguese are available for re-use and replication at: https://lifeinvasaqua.com/campana-revisa-limpia-seca-de-lifeinvasaqua/.

Figure 4. Dissemination and training strategy aimed at knowledge multipliers **A** code of conduct for zoos and aquariums co-created with the Iberian Association of Zoos and Aquariums (AIZA) in 2022 **B** training for zoos, aquariums and museums staff at the National Museum of Natural Sciences (MNCN-CSIC), Madrid 2023.

Guidelines with the best practices and codes of conduct for sectors such as online commerce, surveillance agents and zoos and aquariums (Fig. 4) were elaborated, totaling 16 codes published in Spanish and Portuguese and providing practical recommendations to reduce the risk of IAS introductions and spread (https://lifeinvasaqua.com/codigos-de-conducta-lifeinvasaqua-sobre-especies-exoticas-invasoras/). These documents were widely distributed to the targeted stakeholders and also made available online.

In addition, specific activities and materials targeting teachers and students included 57 events with schools and universities, such as 3 dedicated youth conferences, 76 fieldwork actions and the development of 2 didactic guides, among others. These experiences involved the educational sector in hands-on learning about IAS and ecosystem conservation.

Raise public awareness through mass communication

Disseminating and communicating LIFE INVASAQUA's activities, tools and results among the public was one of the project's main goals. The primary objective of the mass communication campaign was to ensure that project key messages reached a wide audience, including policymakers, environmental managers and the public, fostering understanding and encouraging action on IAS. A comprehensive communication strategy was built based on a preliminary assessment (Banha et al. 2022) that helped to identify relevant knowledge gaps and misunderstandings such as knowledge bias between IAS impacts on biodiversity and human health. This enabled the team to design targeted campaigns that addressed these issues.

The project implemented a wide range of educational and public engagement activities (Fig. 1), including an itinerant exhibition (Fig. 5) in three languages (Spanish, Portuguese and English), titled "Watch out! Aquatic Invaders". This exhibition travelled to major cities and institutions across the Iberian Peninsula, reaching more than 150,000 visitors and significantly promoting public awareness of IAS. In addition, the "Stop Comercio Invasoras" online campaign (https://lifeinvasaqua.com/life-invasaqua-lanza-la-campana-stop-comercio-invasoras-apoyada-por-entidades-de-espana-y-portugal-para-un-comercio-responsable-de-especies-exoticas-coincidiendo-con-el-inicio-de-las/) (Fig. 5) was launched to raise public awareness and prevention of IAS in the e-commerce. It reached 30,000 impressions on the project social media (profile @LifeInvasaqua on Twitter/X) and the endorsement of 60 entities.

Citizen science initiatives were also a keystone of the public engagement activities, which included the design and implementation of the Iberian module for the smartphone App "Invasive Alien Species in Europe" ("IAS in Europe" App). The module was developed in close collaboration with the European Commission Joint Research Centre (JCR EASIN) and the University of Castilla-La Mancha, aiming at involving citizens and key stakeholders in the detection of IAS. It was launched in 2021 and disseminated within various event types (bioblitzes, volunteering with NGOs, angling competitions, etc.). This module contributed to increase participants' knowledge and awareness as well as the recording of 204 new observations (out of the total of 402 citizen science validated reports in JRC EASIN for the Iberian Peninsula), meaning a great increase in the use of the app among the Iberian public. It also helped to test the feasibility of implementation of additional modules of the app at national and regional levels (Trichkova et al. 2021), as well as to make its contents more accessible through translation into Portuguese and Spanish (Gervasini et al. 2022). In parallel, we also developed the user-friendly IBERMIS online platform (https://ibermis.org/), that gathered the information recorded in "IAS in Europe" App, including a map viewer connected with the EASIN map services and all the resources generated by the project. It also included other additional resources such as information on IAS legislation, dissemination materials of other initiatives and training resulting in a resources repository on the aquatic IAS topic for the Iberian Peninsula.

The project participated and organized activities within global events such as the European Researchers Night or the World Rivers Day. Additionally, we conceptualized and co-organized three editions of the "Invasive Species Week in Portugal & Spain" (https://www.speco.pt/sei), an awareness massive event that in 2023 involved 250 entities and more than 2,800 participants.

Figure 5. Dissemination activities to raise public awareness **A** "Watch out! Aquatic Invaders" travelling exhibition in Portugal, 2023 **B** visuals of the "Stop Comercio Invasoras" campaign.

Therefore, the project increased public and stakeholders' awareness as well as built long-term capacity for IAS management by integrating educational efforts with strategic communication.

The project's website (http://www.lifeinvasaqua.com/) attracted more than 150,000 visits, being key in supporting the communication strategy. It served as a hub for news, resources, event announcements and training materials produced in Spanish, Portuguese and English to facilitate access to all Iberian audiences. Social media platforms (active profiles were implemented in Facebook, Twitter/X, LinkedIn and Instagram) amplified the project's visibility, engaging more than 20,000 followers with interactive posts, videos, and infographics that encouraged user interaction and raised awareness about IAS issues. Social media engagement greatly overpassed initial expectations, reaching more than 2 million impressions (Fig. 6). Newsletters were an additional key dissemination tool that were regularly sent to more than 3,500 subscribers, including stakeholders, researchers, and decision-makers.

The project survey served as an evaluation tool and also promoted participants' awareness on the impacts of IAS while filling their answers. This tool proved to be highly effective in both collecting feedback and fostering greater understanding of IAS challenges among respondents.

The project's partnership with EFE Verde agency ensured widespread media coverage, resulting in more than 300 articles and news items in Spanish and Portuguese. This wide media presence extended the project's visibility to broader audiences, including decision-makers and those with highest influence in the environmental sector.

A total of 725 publications and communication materials were produced by the project staff and external collaborators in an extensive variety of formats (e.g., press releases, scientific and non-scientific publications, oral or panel communications at congresses and conferences, etc.). These publications aimed at disseminating information and problems of IAS and spreading the events, resources, and activities of the project.

At the end of the project, LIFE INVASAQUA communication efforts showed a measurable increase in awareness about IAS impacts (Oliva-Paterna et al. 2024a, b). The website, newsletters and social networks effectively reached a variety of

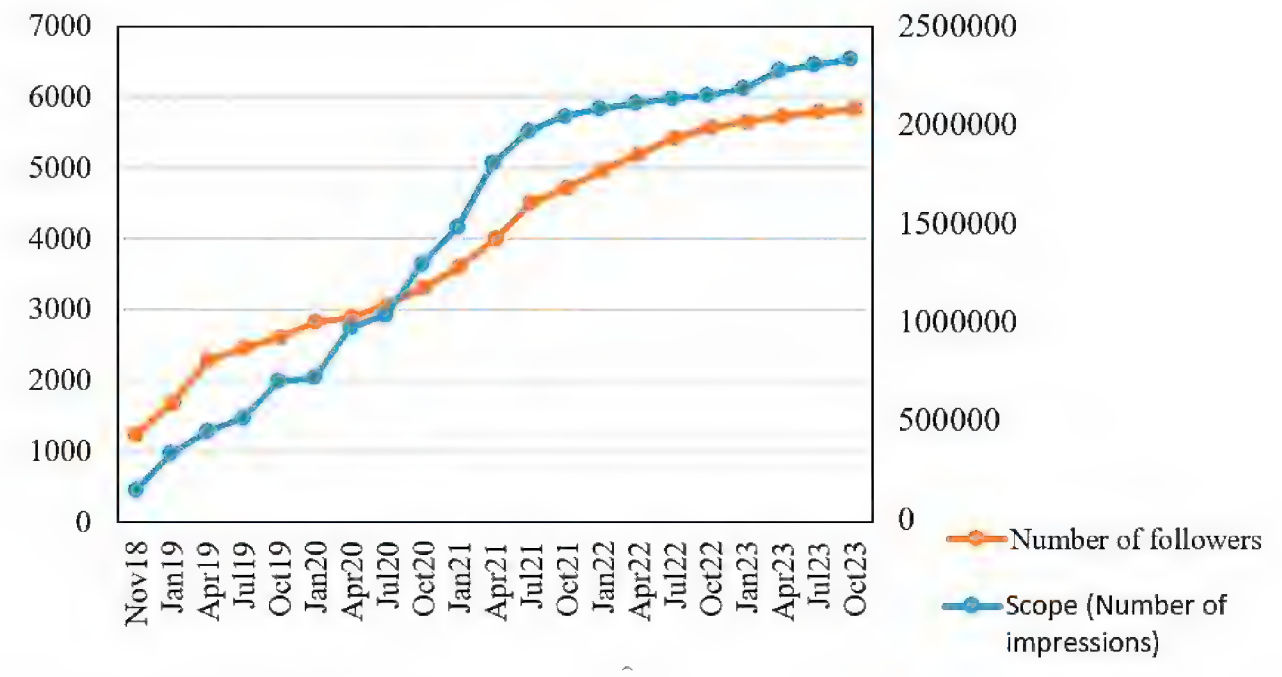

Figure 6. LIFE INVASAQUA social media results. Temporal trends (November 2018 – October 2023) in total number of followers reached (Y-axis left) and the scope (number of impressions) (Y-axis right) on the social network X/Twitter (@LifeInvasaqua account).

audiences with project resources, while the media coverage ensured a sustained public message about IAS management, promoting not only raised awareness but empowering stakeholders and the public with knowledge and tools to take action and providing a legacy of best practices for future replication.

Outlook

The LIFE INVASAQUA project set a baseline for sustained action on freshwater and estuarine IAS management beyond its official duration. To ensure long term implementation, we developed an After-LIFE Plan (Olivo del Amo et al. 2023) supported by key elements and activities identified in the Replicability and Transferability Plan (IUCN and UMU 2023) with greatest potential to be replicated due to its impact and success during the project, including technologies, methodological approaches, good practices or collaborative models. This aimed to influence the promotion of stakeholders and public awareness and engagement as a key aspect to support awareness and IAS management over time (Novoa et al. 2017; Cordeiro et al. 2020). For example, the "Invasive Species Week in Spain and Portugal" built a solid context for the implementation of replication efforts in the subsequent years, with an increasing tendency in scope and impact (edition 2024 involved 235 entities which organized 392 activities, reaching more than 12,000 direct participants). In addition, the travelling exhibition continues live in Portugal and Spain, attracting the attention of potential hosting institutions and visitors among the general public.

The project co-organised the VI National Congress and I Iberian Congress on IAS, held in Pamplona, the SIBIC Conferences latest editions and supported the organization of NEOBIOTA 2024 Conference in Lisbon as well as the EEI2025 Iberian Congress in Murcia (May 2025) to promote the continuity of experts' forums to exchange updated information of IAS management and foster new partnerships and collaborations.

The continued use and update of the "Invasive Alien Species web platform" (in November 2024 it included up to 31,730 records of more than 380 taxa -244 published online-), hosted at the SIBIC website, and the IBERMIS platform being maintained by IUCN-Med, ensures that monitoring and data sharing will

remain as key components in managing IAS, contributing to a more coordinated approach. These tools, along with strategic recommendations for transboundary management and the IAS prioritisation lists (Table 1) provide a lasting legacy to help guide future IAS policies and management efforts at European and National levels. We conceptualised them as live tools that can be updated and further developed to cover future needs on IAS information and prioritisation. In addition, the IBERMIS platform hosted a long-term resources repository on aquatic IAS for the Iberian Peninsula, including the project's MOOCs with self-guided options.

The project partners also keep their commitment to share the results and lessons learned in work meetings and experts' forums such as the survey and workshop on "Establishing transnational collaboration to manage Invasive Alien Species in the European Union" promoted by JRC EASIN in November 2023 (Magliozzi et al. 2024). We also explored new possibilities to keep the involvement of local governments (e.g. Spanish Federation of Provinces and Municipalities) in managing IAS through training and collaboration, and to include the IAS topic in academic curricula at different levels.

Multiple entities, projects and academic societies engaged in transferring information, in facilitating the replication of the project actions and in the development of events for the exchange of experiences. This effort included active participation in knowledge-sharing forums, the organization of conferences, and the promotion of collaborative networks across Europe.

Conclusions and lessons learned

LIFE INVASAQUA demonstrated the critical role of transnational projects in addressing the complex challenges posed by IAS. The project proved to be an important instrument of awareness in the Iberian Peninsula by fostering collaboration between Spain and Portugal, as well as engaging local authorities, stakeholders, and the scientific community. The development of strategic tools, public awareness campaigns and transboundary cooperation initiatives ensured its long-term impact on biodiversity conservation.

The project survey revealed that the most engaged stakeholders and target groups – those the project most actively sought to involve – were users of rivers and estuaries (47.5% of responses) and the educational sector (24.0%). Additionally, relevant insights were gathered from groups directly involved in management, including public administration (5.0%), the scientific community (11.5%), and environmental NGOs (2.3%).

The results indicated a significant increase in awareness across all stakeholder groups and the general public, particularly among those who had previously interacted with the project's resources. For example, in 2023, 64% of survey respondents were already familiar with the LIFE INVASAQUA project and its materials. These findings also demonstrated that the survey was an effective tool for capturing public and stakeholder perceptions regarding IAS issues, as well as for monitoring awareness changes over time.

In addition, the surveys were able to demonstrate that the training sessions and activities carried out under the LIFE INVASAQUA project contributed to improve stakeholders' perception of the impacts of invasive alien species (IAS). As highlighted by Banha et al. (2017, 2022), there is typically a greater and more accurate perception of the impacts of IAS on biodiversity compared to their socioeconomic

and human health effects. However, the final survey results indicate a positive shift, showing enhanced awareness across all three impact categories.

The project also proved to be a good source of information to support the implementation of the EU and national regulations on IAS, providing tools and factual basis for the review of regional enforcement. The information provided was essential to support decision making on IAS that directly or potentially affect the Iberian inland waters, and to ensure the optimal use of the resources invested in prevention and early detection of new species arrival (Epanchin-Niell 2017; Cuthbert et al. 2021). However, given the increase in the number of alien species that are being and will likely be introduced in the coming decades (Seebens et al. 2021), a regular review and update of the information is needed as well as to maintain efforts to raise awareness of the IAS problem.

The project showcased how transnational initiatives can overcome fragmented policies, funding limitations, language barriers, and low public awareness. Its alignment with the EU Biodiversity Strategy and EU Regulation on IAS highlighted the value of international cooperation in mitigating ecological and economic damage. Its focus on replicable tools and long-term impact reinforced the importance of capacity building, shared responsibility, and voluntary compliance in IAS management.

The project provided essential insights to best understand the complexities of managing IAS in aquatic environments. Seven key lessons were learned throughout the project:

1. Importance of transnational cooperation: Effective IAS management requires cooperation between neighbouring countries. The collaboration between Spain and Portugal was key for developing coordinated strategies, such as the creation of shared lists of priority species and transboundary management recommendations.
2. Engagement of stakeholders: The success of IAS management strategies strongly depends on the active involvement of stakeholders, including public administrations, scientific communities, environmental NGOs and local communities. Ensuring diverse stakeholder engagement from the outset helped to strengthen the project's impact and facilitated the integration of the population knowledge into broader management plans.
3. Co-creation: Direct engagement with relevant stakeholders to create, update and improve resources such as the "IAS in Europe" App or the codes of conduct for zoos and aquariums were successful experiences that can be replicated by other projects. These initiatives actively involved relevant entities in content development, thereby enhancing its quality, facilitating broader dissemination, and promoting its adoption by the target audiences.
4. Engagement of challenging groups: Active involvement of key stakeholder groups, such as recreational anglers and pet owners, is essential for the effective management of IAS, as their behaviours can directly influence introduction and spread pathways. It can be often challenging to engage them due to varying levels of awareness, perceived personal impact, or resistance to regulatory measures. To address them by engaging reference institutions that they may feel can be trusted, such as the surveillance agent forces, the veterinary sector or angling federations, is an effective way to ensure that they get access to the key messages and essential knowledge on IAS impacts.

5. Raising awareness: Public awareness and education are essential in addressing IAS issues. Engaging the general public through campaigns, citizen science initiatives and educational events proved to be effective for increasing understanding and encouraging participation in IAS management efforts.
6. Need for adequate resources and coordination: While the project achieved relevant results, challenges remain in allocating sufficient resources and coordination for rapid response mechanisms. Effective IAS management requires both financial investment and political willingness.
7. Monitoring and evaluation: Progress monitoring and evaluation are crucial for assessing the effectiveness of IAS management strategies. The use of detailed metrics, surveys and feedback mechanisms allowed the project to adapt and improve its activities, ensuring that the actions implemented were impactful and evidence-based.

The experience and lessons learned from LIFE INVASAQUA set a solid foundation for future initiatives in the Iberian Peninsula. These findings also offer valuable insights for addressing similar challenges across Europe, emphasizing the importance of shared responsibility, continuous education and the development of innovative frameworks to tackle the growing threat of IAS. Uncertainties remain regarding the long-term efficiency of certain strategies, especially in the face of climate change and evolving ecological conditions. Continued adaptation and collaboration will be essential to address these challenges and ensure the success of IAS management efforts.

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Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

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Author contributions

Celia López-Cañizares: Conceptualization, Project administration, Writing - Original Draft, Writing – review and editing; Francisco J. Oliva-Paterna: Supervision, Conceptualization, Project administration, Funding acquisition, Writing – review and editing; Rosa Olivo del Amo: Conceptualization, Project administration, Writing – review and editing; Mar Torralva, Pedro Anastácio, Fernando Cobo, Anabel Perdices, Rafael Miranda, Catherine Numa: Funding acquisition, Writing – review and editing; Antonio Guillén-Beltrán, Filipe Banha, Pedro Brandão, Sandra Barca, Rufino Vieira-Lanero, Frederic Casals, Jorge R. Sánchez-González, Annie Machordom, Javier Oscoz, Helena Clavero-Sousa, Lourdes Lázaro-Marín, Filipe Ribeiro, Francisco J. Oficialdegui and José M. Zamora-Marín: Writing – review and editing. All authors have reviewed and contributed to improve the text and figures.

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Data availability

All of the data that support the findings of this study are available in the main text and in the project final reports in Oliva-Paterna et al. 2024a and Oliva-Paterna et al. 2024b.

References

Angulo E, Ballesteros-Mejia L, Novoa A, Duboscq-Carra VG, Diagne C, Courchamp F (2021) Economic costs of invasive alien species in Spain. NeoBiota 67: 267–297. https://doi.org/10.3897/neobiota.67.59181

Banha F, Diniz AM, Anastácio PM (2017) The role of anglers' perceptions and habits in biological invasions: Perspectives from the Iberian Peninsula. Aquatic Conservation 27(1): 51–64. https://doi.org/10.1002/aqc.2677

Banha F, Diniz AM, Olivo del Amo R, Oliva-Paterna FJ, Anastácio PM (2022) Perceptions and risk behaviors regarding biological invasions in inland aquatic ecosystems. Journal of Environmental Management 308: 114632. https://doi.org/10.1016/j.jenvman.2022.114632

Boieiro M, Ceia H, Caramujo MJ, Cardoso P, Garcia-Pereira P, Pires D, Reis J, Rego C [Eds] (2023) Livro Vermelho dos Invertebrados de Portugal Continental. FCiências.ID e ICNF IP, Lisboa, 468 pp. https://repositorio.ulisboa.pt/jspui/handle/10451/61805?mode=full

Cogoni A, Brundu G, Caddeo A, Loi MC, Marignani M, Iiriti G, Vaquer G (2017) LIFE ASAP – Increasing awareness on alien species in Italy. Proceedings from the 112° Congresso della Società Botanica Italiana IV International Plant Science Conference (IPSC), Florence, Italy. https://iris.unica.it/handle/11584/238773

Cordeiro B, Marchante H, Castro P, Marchante E (2020) Does public awareness about invasive plants pay off? An analysis of knowledge and perceptions of environmentally aware citizens in Portugal. Biological Invasions 22: 2267–2281. https://doi.org/10.1007/s10530-020-02247-z

Coya R, Rodríguez-Ruiz A, Fueyo Á, Orduna C, Miralles L, de Meo I, Pérez T, Cid JR, Fernández-Delgado C, Encina L, Borrell YJ, Granado-Lorencio C (2025) Environmental DNA and hydroacoustic surveys for monitoring the spread of the Invasive European Catfish (*Silurus glanis* Linnaeus, 1758) in the Guadalquivir River Basin, Spain. Animals (Basel) 15(2): 285. https://doi.org/10.3390/ani15020285

Cruz MJ, Rebelo R (2005) Vulnerability of Southwest Iberian amphibians to an introduced crayfish, *Procambarus clarkii.* Amphibia-Reptilia 26(3): 293–303. https://doi.org/10.1163/156853805774408577

Cuthbert RN, Pattison Z, Taylor NG, Verbrugge L, Diagne C, Ahmed DA, Leroy B, Angulo E, Briski E, Capinha C, Catford JA, Dalu T, Essl F, Gozlan RE, Haubrock PJ, Kourantidou M, Kramer AM, Renault D, Courchamp F (2021) Global economic costs of aquatic invasive alien species. The Science of the Total Environment 775: 145238. https://doi.org/10.1016/j.scitotenv.2021.145238

de Groot M, O'Hanlon R, Bullas-Appleton E, Csóka G, Csiszár Á, Faccoli M, Gervasini E, Kirichenko N, Korda M, Marinšek A, Robinson N, Shuttleworth C, Sweeney J, Tricarico E, Verbrugge L, Williams D, Zidar S, Kus Veenvliet J (2020) Challenges and solutions in early detection, rapid response and communication about potential invasive alien species in forests. Management of Biological Invasions: International Journal of Applied Research on Biological Invasions 11(4): 637–660. https://doi.org/10.3391/mbi.2020.11.4.02

De Santis V, Brignone S, Čech M, Eckert EM, Fontaneto D, Magalhães F, Martelo J, Ribeiro F, Vejřík L, Volta P (2024) LIFE PREDATOR: Prevent, detect, combat the spread of *Silurus glanis* in south European lakes to protect biodiversity. NeoBiota 93: 225–244. https://doi.org/10.3897/neobiota.93.105200

Decreto Lei (2019) Decreto Lei 92/2019 Lista Nacional de Espécies Invasoras. https://dre.pt/dre/detalhe/decreto-lei/92-2019-123745491

Diagne C, Leroy B, Vaissière AC, Gozlan RE, Roiz D, Jarić I, Salles JM, Bradshaw CJA, Courchamp F (2021) High and rising economic costs of biological invasions worldwide. Nature 592: 571–576. https://doi.org/10.1038/s41586-021-03405-6

Doadrio I [Ed.] (2001) Atlas y Libro Rojo de los Peces Continentales de España. Museo Nacional de Ciencias Naturales, Dirección General de Conservación de la Naturaleza, Madrid. https://www.miteco.gob.es/es/biodiversidad/temas/inventarios-nacionales/inventario-especies-terrestres/inventario-nacional-de-biodiversidad/ieet_peces_atlas.html

Epanchin-Niell RS (2017) Economics of invasive species policy and management. Biological Invasions 19: 3333–3354. https://doi.org/10.1007/s10530-017-1406-4

Essl F, Lenzner B, Courchamp F, Dullinger S, Jeschke JM, Kühn I, Leung B, Moser D, Roura-Pascual N, Seebens H (2019) Introducing AlienScenarios: A project to develop scenarios and models of biological invasions for the 21st century. NeoBiota 45: 1–17. https://doi.org/10.3897/neobiota.45.33366

Flood PJ, Duran A, Barton M, Mercado-Molina AE, Trexler JC (2020) Invasion impacts on functions and services of aquatic ecosystems. Hydrobiologia 847: 1571–1586. https://link.springer.com/article/10.1007/s10750-020-04211-3

Gallardo B, Clavero M, Sánchez MI, Vilà M (2016) Global ecological impacts of invasive species in aquatic ecosystems. Global Change Biology 22: 151–163. https://doi.org/10.1111/gcb.13004

Gallardo B, Bogan AE, Harun S, Jainih L, Lopes-Lima M, Pizarro M, Rahim KA, Sousa R, Virdis SGP, Zieritz A (2018) Current and future effects of global change on a hotspot's freshwater diversity. The Science of the Total Environment 635: 750–760. https://doi.org/10.1016/j.scitotenv.2018.04.056

Gallardo B, Bacher S, Bradley B, Comín FA, Gallien L, Jeschke JM, Sorte CJB, Vilà M (2019) InvasiBES: Understanding and managing the impacts of Invasive alien species on Biodiversity and Ecosystem Services. NeoBiota 50: 109–122. https://doi.org/10.3897/neobiota.50.35466

Gervasini E, López-Cañizares C, Cardoso AM, Spinelli F, Tsiamis K, Schade S (2022) Assessing changing biodiversity – Public engagement in the monitoring of invasive alien species in Europe, Publications Office of the European Union, Luxembourg. https://data.europa.eu/doi/10.2760/184991

Haubrock PJ, Turbelin AJ, Cuthbert RN, Novoa A, Taylor NG, Angulo E, Ballesteros-Mejia L, Bodey TW, Capinha C, Diagne C, Essl F, Golivets M, Kirichenko N, Kourantidou M, Leroy B, Renault D, Verbrugge L, Courchamp F (2021) Economic costs of invasive alien species across Europe In: Zenni RD, McDermott S, GarcíaBerthou E, Essl F (Eds) The economic costs of biological invasions around the world. NeoBiota 67: 153–190. https://doi.org/10.3897/neobiota.67.58196

Hulme PE (2021) Unwelcome exchange: International trade as a direct and indirect driver of biological invasions worldwide. One Earth 4(5): 666–679. https://doi.org/10.1016/j.oneear.2021.04.015

IPBES (2023) Summary for Policymakers of the Thematic Assessment Report on Invasive Alien Species and their Control of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. In: Roy HE, Pauchard A, Stoett P, Renard Truong T, Bacher S, Galil BS, Hulme PE, Ikeda T, Sankaran KV, McGeoch MA, Meyerson LA, Nuñez MA, Ordonez A, Rahlao SJ, Schwindt E, Seebens H, Sheppard AW, Vandvik V (Eds) IPBES Secretariat, Bonn, Germany. https://doi.org/10.5281/zenodo.7430692

IUCN and UMU (2023) LIFE INVASAQUA. Transferability and replicability plan. Technical document of the LIFE INVASAQUA project (LIFE17 GIE/ES/000515). Centre for Mediterranean Cooperation, Málaga, Spain. https://lifeinvasaqua.com/wp-content/uploads/2023/11/Transferability-Replicability-Plan_EN.pdf

Katsanevakis S, Zaiko A, Olenin S, Costello MJ, Gallardo B, Tricarico E, Adriaens T, Jeschke JM, Sini M, Burke N, Ellinas K, Rutten S, Poursanidis D, Marchini A, Brys R, Raeymaekers JAM, Noé N, Hermoso V, Blaalid R, Lucy FE, Verbrugge LNH, Staehr PAU, Vandepitte L, de Groot D, Elliott M, Reuver M, Maclaren J, Li M, Oldoni D, Mazaris A, Trygonis V, Hablützel PI, Everts T, Pistevos JCA, Dekeyzer S, Kimmig SE, Rickowski FS, Panov VE (2024) GuardIAS – Guarding European Waters from Invasive Alien Species. Management of Biological Invasions : International Journal of Applied Research on Biological Invasions 15(4): 701–730. https://doi.org/10.3391/mbi.2024.15.4.14

Magalhães MF, Amaral SD, Sousa M, Alexandre CM, Raposo de Almeida P, Alves, MJ, Cortes R, Farrobo A, Filipe, AF, Franco A, de Jesus J, Oliveira JM, Pereira J, Pires D, Reis M, Ribeiro F, Robalo JI, Sá F, Sousa Santos C, Teixeira A, Domingos I (2023) Livro Vermelho dos Peixes Dulceaquícolas e Diádromos de Portugal Continental. FCiências.ID e ICNF IP, Lisboa. https://repositorio.ulisboa.pt/handle/10451/60003

Magliozzi C, Lucrezi S, Oficialdegui FJ, Gervasini E, Melone B, Cardoso AC (2024) Transnational cooperation in EU: Opportunities for addressing invasive alien species. Management of Biological Invasions: International Journal of Applied Research on Biological Invasions 15(4): 683–700. https://doi.org/10.3391/mbi.2024.15.4.13

McFadden IR, Sendek A, Brosse M, Bach PM, Baity-Jesi M, Bolliger J, Bollmann K, Brockerhoff EG, Donati G, Gebert F, Ghosh S, Ho H, Khaliq I, Lever JJ, Logar I, Moor H, Odermatt D,

Pellissier L, de Queiroz LJ, Rixen C, Schuwirth N, Shipley JR, Twining CW, Vitasse Y, Vorburger C, Wong MKL, Zimmermann NE, Seehausen O, Gossner MM, Matthews B, Graham CH, Altermatt F, Narwani A (2023) Linking human impacts to community processes in terrestrial and freshwater ecosystems. Ecology Letters 26(2): 203–218. https://doi.org/10.1111/ele.14153

MITECO (2019) Estrategia de gestión, control y posible erradicación del camalote (*Eichhornia crassipes*). Ministerio para la Transición Ecológica, 49 pp. https://www.miteco.gob.es/en/biodiversidad/publicaciones/pbl_fauna_flora_estrategia_camalote.html

Muñoz-Mas R, García-Berthou E (2020) Alien animal introductions in Iberian inland waters: An update and analysis. The Science of the Total Environment 703: 134505. https://doi.org/10.1016/j.scitotenv.2019.134505

Novoa A, Dehnen-Schmutz K, Fried J, Vimercati G, Kumschick S, Pyšek P, Richardson DM, Wilson JRU (2017) Does public awareness increase support for invasive species management? Promising evidence across taxa and landscape types. Biological Invasions 19: 3691–3705. https://doi.org/10.1007/s10530-017-1592-0

Nunes AL, Tricarico E, Panov VE, Cardoso AC, Katsanevakis S (2015) Pathways and gateways of freshwater invasions in Europe. Aquatic Invasions 10: 359–370. https://doi.org/10.3391/ai.2015.10.4.01

Oficialdegui FJ, Zamora-Marín JM, Guareschi S, Anastácio PM, García-Murillo P, Ribeiro F, Miranda R, Cobo F, Gallardo B, García-Berthou E, Boix D, Arias A, Cuesta JA, Medina L, Almeida D, Banha F, Barca S, Biurrun I, Cabezas MP, Calero S, Campos JA, Capdevila-Argüelles L, Capinha C, Casals F, Clavero M, Encarnação J, Fernández-Delgado C, Franco J, Guillén A, Hermoso V, Machordom A, Martelo J, Mellado-Díaz A, Morcillo F, Oscoz J, Perdices A, Pou-Rovira Q, Rodríguez-Merino A, Ros M, Ruiz-Navarro A, Sánchez MI, Sánchez-Fernández D, Sánchez-González JR, Sánchez-Gullón E, Teodósio MA, Torralva M, Vieira-Lanero R, Oliva-Paterna FJ (2023a) A horizon scan exercise for aquatic invasive alien species in Iberian inland waters. The Science of the Total Environment 869: 161798. https://doi.org/10.1016/j.scitotenv.2023.161798

Oficialdegui FJ, Anastácio PM, Miranda R, Cobo F, González-Ortegon E, Zamora-Marín JM, Arias A, Benejam L, Banha F, Clavero M, Cuesta JA, Oscoz J, Pou-Rovira Q, Oliva-Paterna FJ (2023b) Strategic recommendations for the transnational management of invasive alien crayfish and crabs in Iberian inland waters. Technical Report prepared by LIFE INVASAQUA (LIFE17 GIE/ES/000515). https://ibermis.org/en/recomendaciones-estrategicas-para-la-gestion-transnacional-de-cangrejos-exoticos-invasores-en-aguas-interiores-ibericas/

Oliva-Paterna FJ, Ribeiro F, Miranda R, Anastácio PM, García-Murillo P, Cobo F, Gallardo B, García-Berthou E, Boix D, Medina L, Morcillo F, Oscoz J, Guillén A, Arias A, Cuesta JA, Aguiar F, Almeida D, Ayres C, Banha F, Barca S, Biurrun I, Cabezas MP, Calero S, Campos JA, Capdevila-Argüelles L, Capinha C, Carapeto A, Casals F, Chainho P, Cirujano S, Clavero M, Del Toro V, Encarnação JP, Fernández-Delgado C, Franco J, García-Meseguer AJ, Guareschi S, Guerrero A, Hermoso V, Machordom A, Martelo J, Mellado-Díaz A, Moreno JC, Oficialdegui FJ, Olivo del Amo R, Otero JC, Perdices A, Pou-Rovira Q, Rodríguez-Merino A, Ros M, Sánchez-Gullón E, Sánchez MI, Sánchez-Fernández D, Sánchez-González JR, Soriano O, Teodósio MA, Torralva M, Vieira-Lanero R, Zamora-López A, Zamora-Marín JM (2021a) List of aquatic alien species of the Iberian Peninsula 2020: Updated list of the aquatic alien species introduced and established in Iberian inland waters. Technical Report prepared by LIFE INVASAQUA (LIFE17 GIE/ES/000515), 64 pp. https://www.miteco.gob.es/content/dam/miteco/es/biodiversidad/temas/conservacion-de-especies/listadeespeciesexoticasacuaticasdelapeninsulaiberica_tcm30-529356.pdf

Oliva-Paterna FJ, Ribeiro F, Miranda R, Anastácio PM, García-Murillo P, Cobo F, Gallardo B, García-Berthou E, Boix D, Medina L, Morcillo F, Oscoz J, Guillén A, Arias A, Cuesta JA, Aguiar F, Almeida D, Ayres C, Banha F, Barca S, Biurrun I, Cabezas MP, Calero S, Campos JA, Capdevila-Argüelles L, Capinha C, Carapeto A, Casals F, Chainho P, Cirujano S, Clavero M, Del Toro V, Encarnação JP,

Fernández-Delgado C, Franco J, García-Meseguer AJ, Guareschi S, Guerrero A, Hermoso V, Machordom A, Martelo J, Mellado-Díaz A, Moreno JC, Oficialdegui FJ, Olivo del Amo R, Otero JC, Perdices A, Pou-Rovira Q, Rodríguez-Merino A, Ros M, Sánchez-Gullón E, Sánchez MI, Sánchez-Fernández D, Sánchez-González JR, Soriano O, Teodósio MA, Torralva M, Vieira-Lanero R, Zamora-López A, Zamora-Marín JM (2021b) List of potential aquatic alien species of the Iberian Peninsula 2020: Updated list of the potential aquatic alien species with high risk of invasion in Iberian inland waters. Technical Report prepared by LIFE INVASAQUA (LIFE17 GIE/ES/000515), 60 pp. https://lifeinvasaqua.com/wp-content/uploads/2021/04/TR2_Invasaqua_ING_PDF_interact.pdf

Oliva-Paterna FJ, Oficialdegui FJ, Anastácio PM, García-Murillo P, Zamora-Marín JM, Ribeiro F, Miranda R, Cobo F, Gallardo B, García-Berthou E, Boix D, Medina L, Arias A, Cuesta JA, Almeida D, Banha F, Barca S, Biurrun I, Cabezas MP, Calero S, Campos JA, Capdevila-Argüelles L, Capinha C, Casals F, Clavero M, Encarnação JP, Fernández-Delgado C, Franco J, Guareschi S, Guillén A, Hermoso V, López-Cañizares C, Machordom A, Martelo J, Mellado-Díaz A, Morcillo F, Olivo del Amo R, Oscoz J, Perdices A, Pou-Rovira Q, Rodríguez-Merino A, Ros M, Ruiz-Navarro A, Sánchez-Gullón E, Sánchez MI, Sánchez-Fernández D, Sánchez-González JR, Teodósio MA, Torralva M, Vieira-Lanero R (2022) Black list and alert list of the aquatic invasive alien species of the Iberian Peninsula: Horizon scanning exercise focused on the high-risk aquatic invasive alien species for the Iberian inland waters. Technical Report prepared by LIFE INVASAQUA (LIFE17 GIE/ES/000515), 57 pp. https://doi.org/10.1016/j.scitotenv.2023.161798

Oliva-Paterna FJ, Oficialdegui FJ, Sánchez-González JR, Zamora-Marín JM, Casals F, Ribeiro F, Torralva M, Miranda R, Guerreiro PM, Almeida D, Alexandre CM, Benejam L, Clavero M, Cobo F, Doadrio I, Fernández-Delgado C, García-Berthou E, Godinho FN, González G, Magalhães MF, Morcillo F, Perdices A, Pou-Rovira Q, Santos JM, Vila-Gispert A, Zamora L (2023) Strategic recommendations for the transnational management of invasive alien fish in Iberian inland waters. Technical Report prepared by LIFE INVASAQUA (LIFE17 GIE/ES/000515). https://lifeinvasaqua.com/wp-content/uploads/2023/02/2023_StrategicRecommendations_Fish_Final_WEB-1.pdf

Oliva-Paterna FJ, Olivo del Amo R, López-Cañizares C, Guillén Beltrán A, Torralva M, Anastácio PM, Banha F, Brandão P, Miranda R, Oscoz J, Cobo F, Barca S, Casals F, Ribeiro F, Perdices A, Clavero-Sousa H, Numa C (2024a) LIFE INVASAQUA – Aquatic invasive alien species of freshwater and estuarine systems: awareness and prevention in the Iberian Peninsula. Actions, Key-Instruments & Lessons Learned. Technical Report prepared by LIFE INVASAQUA (LIFE17 GIE/ES/000515). https://lifeinvasaqua.com/wp-content/uploads/2024/01/LIBRO-6-para-web.pdf

Oliva-Paterna FJ, Olivo del Amo R, López-Cañizares C, Guillén-Beltrán A, Banha F, Brandão P, Anastácio PM (2024b) LIFE INVASAQUA – Aquatic invasive alien species of freshwater and estuarine systems: Awareness and prevention in the Iberian Peninsula. Project visibility, impact & lessons learned. Technical Report prepared by LIFE INVASAQUA (LIFE17 GIE/ES/000515). https://lifeinvasaqua.com/wp-content/uploads/2024/01/LIBRO-7-para-web.pdf

Olivo del Amo R, López-Cañizares C, Oliva-Paterna FJ (2023) After-LIFE communication plan of the project: Freshwater and estuarine invasive alien species: Awareness and prevention in the Iberian Peninsula. Prepared in English, Spanish, and Portuguese by LIFE INVASAQUA (LIFE17 GIE/ES/000515). https://lifeinvasaqua.com/wp-content/uploads/2024/01/POST-LIFE-FINAL.pdf

Real Decreto (2013) Real Decreto 630/2013, de 2 de agosto, por el que se regula el Catálogo español de especies exóticas invasoras. BOE-A-2013-8565. https://www.boe.es/eli/es/rd/2013/08/02/630

Regulation EU (2014) Regulation (EU) No 1143/2014 of the European Parliament and of the Council of 22 October 2014 on the prevention and management of the introduction and spread of invasive alien species. Official Journal of the European Union 57: 1–33. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32014R1143

Roura-Pascual N, Saul WC, Pérez-Granados C, Rutting L, Peterson GD, Latombe G, Essl F, Adriaens T, Aldridge DC, Bacher S, Bernardo-Madrid R, Brotons L, Diaz F, Gallardo B, Genovesi P, Golivets M,

González-Moreno P, Hall M, Kutlesa P, Lenzner B, Liu C, Pagitz K, Pastor T, Rabitsch W, Robertson P, Roy HE, Seebens H, Solarz W, Starfinger U, Tanner R, Vilà M, Leung B, Garcia-Lozano C, Jeschke JM (2024) A scenario-guided strategy for the future management of biological invasions. Frontiers in Ecology and the Environment 22(4): 151–163. https://doi.org/10.1002/fee.2725

Ruiz-Navarro A, Torralva M, Oliva-Paterna FJ (2013) Trophic overlap between cohabiting populations of invasive mosquitofish and an endangered toothcarp at changing salinity conditions. Aquatic Biology 19: 1–11. https://doi.org/10.3354/ab00512

Ruiz-Navarro A, Esteve P, Baños-González F, Díaz-Tárraga F (2023) Students' perceptions of the presence of feral exotic pets and influencing factors. Journal of Biological Education 12: 1–19. https://doi.org/10.1080/00219266.2023.2288326

Seebens H, Blackburn TM, Dyer EE, Genovesi P, Hulme PE, Jeschke JM, Pagad S, Pyšek P, Winter M, Arianoutsou M, Bacher S, Blasius B, Brundu G, Capinha C, Celesti-Grapow L, Dawson W, Dullinger S, Fuentes N, Jäger H, Kartesz J, Kenis M, Kreft H, Kühn I, Lenzner B, Liebhold A, Mosena A, Moser D, Nishino M, Pearman D, Pergl J, Rabitsch W, Rojas-Sandoval J, Roques A, Rorke S, Rossinelli S, Roy HE, Scalera R, Schindler S, Štajerová K, Tokarska-Guzik B, van Kleunen M, Walker K, Weigelt P, Yamanaka T, Essl F (2017) No saturation in the accumulation of alien species worldwide. Nature Communications 8: 14435. https://doi.org/10.1038/ncomms14435

Seebens H, Bacher S, Blackburn TM, Capinha C, Dawson W, Dullinger S, Genovesi P, Hulme PE, van Kleunen M, Kühn I, Jeschke JM, Lenzner B, Liebhold AM, Pattison Z, Pergl J, Pyšek P, Winter M, Essl F (2021) Projecting the continental accumulation of alien species through to 2050. Global Change Biology 27: 970–982. https://doi.org/10.1111/gcb.15333

Trichkova T, Paunović M, Cogălniceanu D, Schade S, Todorov M, Tomov R, Stănescu F, Botev I, López-Cañizares C, Gervasini E, Hubenov Z, Ignatov K, Kenderov M, Marinković N, Mitton I, Preda C, Spinelli FA, Tsiamis K, Cardoso AC (2021) Pilot application of 'Invasive Alien Species in Europe' smartphone app in the Danube Region. Water (Basel) 13(21): 2952. https://doi.org/10.3390/w13212952

Verdú JR, Numa C, Galante E [Eds] (2011) Atlas y Libro Rojo de los Invertebrados Amenazados de España (Especies Vulnerables). Dirección General de Medio Natural y Política Forestal, Ministerio de Medio Ambiente, Medio Rural y Marino, Madrid, 1318 pp. https://www.miteco.gob.es/es/biodiversidad/temas/inventarios-nacionales/inventario-especies-terrestres/inventario-nacional-de-biodiversidad/ieet_invert_vulne_atlas.html

Zamora-Marín JM, Ruiz-Navarro A, Oficialdegui FJ, Anastácio PM, Miranda R, García-Murillo P, Cobo F, Ribeiro F, Gallardo B, García-Berthou E, Boix D, Medina L, Morcillo F, Oscoz J, Guillén A, Herrero-Reyes AA, Aguiar FC, Almeida D, Arias A, Ayres C, Banha F, Barca S, Biurrun I, Cabezas MP, Calero S, Campos JA, Capdevila-Argüelles L, Capinha C, Carapeto A, Casals F, Chainho P, Cirujano S, Clavero M, Cuesta JA, Deltoro V, Encarnação J, Fernández-Delgado C, Franco J, García-Meseguer AJ, Guareschi S, Guerrero-Gómez A, Hermoso V, López-Cañizares C, López-Soriano J, Machordom A, Martelo J, Mellado-Díaz A, Moreno JC, Olivo del Amo R, Otero JC, Perdices A, Pou-Rovira Q, Quiñonero-Salgado S, Rodríguez-Merino A, Ros M, Sánchez-Gullón E, Sánchez MI, Sánchez-Fernández D, Sánchez-González JR, Soriano O, Teodósio MA, Torralva M, Vieira-Lanero R, Zamora-López A, Oliva-Paterna FJ (2023) A multi-taxa assessment of aquatic non-indigenous species introduced into Iberian freshwater and transitional waters. NeoBiota 89: 17–44. https://doi.org/10.3897/neobiota.89.105994